A Before and After Study of Delay at Selected Intersections in South Lyon

FAST-TRAC PHASE III Deliverable

#9 Comparison of SCATS control versus a simulated control Algorithm

part 1

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William C. Taylor, Ph.D
Brian Wilshon Ph.D

FAST-TRAC Evaluation
Technology Planning and Evaluation Group (TPEG)
Intelligent Transportation Systems Laboratory
University of Michigan
Ann Arbor MI 48109

Steve Underwood, Ph.D Principal Investigator
Zakia R.Shaikh, M.E., Project Manager

Program Offices Telephone
(313) 764 4333

Program Offices Facsimile
(313) 383 1764

A Before and After Study of Delay at Selected Intersections in South Lyon (Field Study Results)

By:
Dr. William C. Taylor
Dr. Brian Wolshon

(Part 1 of Deliverable Number 9)

ABSTRACT

The City of South Lyon recently converted the traffic signals on the street network from fixed time control to the Sydney Coordinated Adaptive Traffic System (SCATS). The objective of this research study was to analyze the differences in certain delay parameters between SCATS control and the pre-existing signal system.

The analyses included a comparison of delay under the fixed time signal system in place before SCATS was implemented and under SCATS. The measures of effectiveness included total intersection delay and the percentage of vehicles required to stop at the intersection from the two approaches representing the critical volumes for the purpose of signal timing.

In the comparison between field data collected under the system in place before SCATS, and the SCAT system, the new system resulted in lower average delay in spite of a slight increase in volume. This change was composed of a decrease in delay for the major movement and an increase in delay to the minor traffic movement. The percent of vehicles required to stop at the signal was reduced for both the major movement and the minor movement.

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1.0 Introduction

The City of South Lyon recently converted the control of its signalized traffic network from optimized fixed-time control to the Sydney Coordinated Adaptive Traffic System (SCATS). SCATS is an automated, real time, traffic responsive signal control strategy. Under SCATS, the timing of the signals is governed by a computer-based control logic. The system has the ability to modify signal timings on a cycle-by-cycle basis using traffic flow information collected at the intersection approach stop lines.

The expected benefit from such a system comes from its ability to constantly modify signal timing patterns to most effectively accommodate changing traffic conditions. The objectives of this research study were to compare the delay at selected intersections in the City of South Lyon between the existing traffic signal timing plan and the SCAT system.

1.1 FAST-TRAC and SCATS

The South Lyon signal improvement project is a small segment of the FAST-TRAC (Faster and Safer Travel - Through Routing and Advanced Controls) Project.“’ FAST-TRAC has involved the conversion of more than 300 pretimed and actuated signalized intersections in Oakland County to SCATS control and has established a regional, route navigation system.[2,3] While FAST-TRAC has been managed primarily by the Road Commission for Oakland County (RCOC), it has been a cooperative effort between many federal, state, county, and local government agencies; as well as private corporations and universities.

The SCATS system was originally developed in the 1970's by the Roads and Traffic Authority of New South Wales, Australia. The system used in this study is version 5.03A. The operational aspect of SCATS has been compared to the type of control "provided by a traffic control officer stationed at the intersection controlling traffic to insure that congestion is reasonably equal among the various approaches. The primary difference is that today's real time adaptive control systems can anticipate the arrival of vehicles from preceding intersections and adjust the signal timing to provide a green phase to match the arrivaltime." [(4)] It functions by making constant modifications to traffic signal timings in real-time in response to the variations in traffic demand and system capacity. It has advantages over the police officer by evaluating and controlling the signal system on a system wide basis rather than on an isolated intersection by intersection basis. It operates by using traffic sensors to monitor flow conditions and thus coordinate signal timings in order to minimize stops and delay time when the system is at or near capacity. SCATS attempts to maximize the system capacity and minimize the possibility of traffic jams by controlling the formation of queues. One of the ways that SCATS accomplishes this is by providing a progression of green signal phases to reduce stopped vehicle queues, thereby reducing delay and decreasing the network travel times. [(3)]

Input data for the SCATS system is collected via a system of traffic sensors. The sensors may be inductive loop detectors imbedded in the pavement, or, as in the case of the South Lyon system, video image devices mounted overhead on the signal strain poles or attached on mast arms. The traffic information collected in the field involves the discharge characteristics (i.e., flow and occupancy during the green phase) on each intersection approach. This data is transmitted to a regional control center where the SCATS control program attempts to most effectively maintain the highest degree of saturation on the intersection downstream of the collected traffic data.

SCATS divides the network into systems and subsystems. Each subsystem contains a single “critical“ intersection, usually where two high volume roadways intersect. SCATS control logic incorporates a dynamic process whereby intersection signal phasing is coordinated. This system is known as “marriage” and “divorce.” Married intersections coordinate timings to allow platoons of traffic to pass through. A divorce occurs when two intersections no longer require coordination to maximize traffic flow through the network. The divorce is implemented after three consecutive cycles warrant a divorce, ensuring additional stability within the system.

Another advantage which SCATS provides over conventional fixed timed systems is the ability to modify timing strategies to fit various control philosophies and to collect, process, and maintain a history of traffic statistics for an area. Signal phases can be set to equalize saturation on all approaches or they can be arranged to give priority to a particular direction of importance. Since the SCATS system requires the use of certain traffic data information it has the ability to record and store these statistics to monitor the strategic performance of the system, detect signal faults, and allow manual overrides of the signals under special operating circumstances.

1.2 The South Lvon Traffic Network

Oakland County is located in the southeastern comer of Michigan, immediately north of the City of Detroit. Throughout the past 15 to 20 years Oakland County has experienced a rapid growth in commercial and residential development. Accompanying the growth in development was an equally significant increase in traffic congestion.[5] The City of South Lyon is located in the southwest comer of Oakland County, approximately 40 miles northwest of the City of Detroit. It is presently a small, semi-rural/suburban community of approximately 25,000 people. The traffic congestion problems are minor compared to many cities in Oakland County. However, like the rest of Oakland County, the land within the City and surrounding Township is experiencing considerable commercial and residential development and increases in the amount of traffic congestion are expected to follow. It was expected that the introduction of the SCATS system of advanced traffic management will allow the community of South Lyon to accommodate the anticipated increases in traffic in a cost effective and efficient manner.

The South Lyon road network is arranged in a perpendicular grid system of primary roadways. The major roads are spaced at approximately one mile intervals. The lone exception to the grid layout is Reynold Sweet Parkway. The Parkway serves as a bypass route for through traffic around the central business district. The majority of the South Lyon traffic load is carried on Pontiac Trail and Ten Mile Road. Pontiac Trail is the main north-south arterial roadway in South Lyon, providing access to Interstate 96 which is located approximately four miles north of town. The overwhelming majority of commercially developed land within South Lyon is located directly adjacent to Pontiac Trail. Ten Mile Road is the prime east-west arterial serving the traffic demand to the commercial centers located to the east.

There were six signalized intersections in operation within the South Lyon traffic network during the study period of 19951996. The installation, operation, and maintenance of these signals are under the jurisdiction of the Road Commission for Oakland County, which has a policy of checking the coordination of their signal systems at least once every two years. Originally, these signals operated on a coordinated pre-timed basis. No traffic adaptive control measures, like actuated signal timing, were present in South Lyon. The relative isolation of South Lyon and its small signal network make it a good "laboratory" for an evaluation of the SCATS system of advanced traffic management. The Oakland County ATMS project involved the conversion of all six signals to SCATS control.

2.0 Prior Studies

Several studies of adaptive control have been carried out by the creators of SCATS, the Australian Road Research Board (ARRB) and the Road and Traffic Authority of New South Wales. One study evaluated SCATS against various forms of non-adaptive forms of signal traffic control.[6] This study measured the performance of SCATS against the control characteristics afforded by systems with isolated fixed time signal phasing and TRANSYT optimized fixed time control with and without local vehicle actuation.

The ARRB study made their comparison using the floating car travel time estimation technique to record the "journey" or travel time on each link, the number of stops in each link, the stopped time in each link, and the amount of fuel used in each trip. The recorded stopped times were later found to be unreliable, so they could not be used in the analysis. The study was able to compare the different signal systems in terms of travel time, number of stops, and a derived "Performance Index." The Performance Index was a weighted measure of travel time incorporating the number of stops during the trip. The study found that on one arterial highway, SCATS resulted in a 23% reduction in travel time and a 46% reduction in stops over isolated fixed time signals. In the central business district (CBD) study area, the travel time was not effected and the reduction in stops was 8%. When compared to Linked Vehicle Actuated (LVA) control, SCATS showed some benefits and some degradations in the recorded performance measures on the arterial and in the CBD areas. The comparison of SCATS and TRANSYT optimized fixed times concluded that SCATS can improve travel time and number of stops from 3% to 18%. The actual improvement depends upon the type of road system (CBD network, arterial corridor, etc.) under study.

3.0 Objectives

The objectives of the South Lyon ATMS evaluation project were to analyze the changes in intersection delay within the South Lyon signalized road network as a result of the addition of the SCATS signal control management system. To accomplish this objective, this study included extensive data collection and statistical analysis. Data collection was carried out using field observation and video image sensing. To determine the extent of the difference in quantifiable terms and document the results, the measures of effectiveness (MOE) used in the study include the average delay per vehicle, the percentage of vehicles stopping at the intersection and the average stopped delay. An analysis was also made of the changes in green time allocation between the two systems. The measures selected for this study were based on their relevance to the goal of reducing traffic delays in the community of South Lyon.

3.1. Total Intersection Delay

The delay at an intersection is defined as the difference in travel time experienced by a vehicle as it is affected by the traffic control at an intersection. It includes the “lost” time due to deceleration and stopped delay.[7] Many different analysis techniques for the calculation of total intersection delay have been developed. [8] The most widely used employ mathematical models to calculate various aspects of total delay which are the result of vehicle arrival patterns.

3.2 Approach Delay

The research study also assessed the difference in the average delay per approach. The term approach delay as used in this study is defined as the length of time that vehicles approaching the intersection from a particular direction are delayed due to a red signal phase and/or a stopped queue in front of them which prohibits their travel through the intersection.[8] In addition this study included an analysis of changes in the average stopped delay per vehicle on a given approach during a specified time interval. This is the measure by which the Highway Capacity Manual[9] assigns a Level of Service (LOS) rating to signal controlled intersections.

4.0 Data Collection

The data collection phase of the study involved the collection of both physical elements and traffic flow parameters of the South Lyon traffic network. The physical elements of the system include features of the road network such as the number of approach lanes and use configurations, as well as traffic control measures such as posted speed limits.

A typical SCATS data file contains several important pieces of data which can be used to analyze the operation of the signal and traffic conditions. It is made up of a stream of data records that include a cycle-by-cycle history of signal phase splits, cycle length, and approach degree of saturation. Using relatively simple computer programs, the files can be sorted and the pertinent traffic volume and signal timing information extracted for use.

The traffic volume and signal timing data for the SCATS analyses were collected only after a sixty day “acquaintance and adjustment” period had taken place. The adjustment period was required for several reasons. Most important, it allows drivers to adjust to the new signal phasing strategies. SCATS is not only real-time adaptive, it may also adjust, rearrange, or eliminate certain phases from cycle to cycle. Thus, drivers who were familiar with the fixed time signal operation were allowed to adjust their driving habits to fit the new SCATS control plans. The adjustment period also allowed the Road Commission for Oakland County time to “fine tune” the operation of the SCATS system.

4.1. “Before” Data

The collection of the “before” traffic volume and traffic signal timing data took place during the spring, summer and fall of 1995; prior to the implementation of the SCATS signal control and Autoscope video imaging system. The fixed time signal timing data was collected during a field visit on April 22, 1995 and verified against Road Commission signal log records.

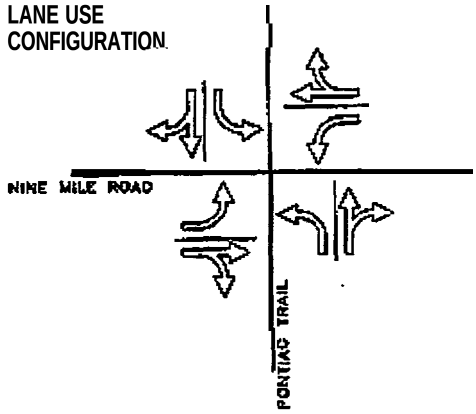
The “before” signal cycle lengths, phase patterns, and intersection approach lane geometry for the two intersections included in this analysis are illustrated in Figure 1. The cycle lengths at all intersections, except for the Pontiac Trail/Eleven Mile Road signal, were 80 seconds. At this location the traffic signal was set to a cycle length of 70 seconds. Thus, there was no coordinated progression on Pontiac Trail between Ten Mile and Eleven Mile Roads.

The road geometry of the link segments and intersection approaches was measured at the same time as the traffic signal timings. All of the approaches to the study intersections featured an exclusive left turn lane. With the exception of the south approach to the Pontiac Trail/Eleven Mile Road intersection, all approaches to the study intersections also featured shared through/right turn lanes. Yone of these approach geometries were altered during or between the “before” and “after phases of the study. Originally, there was no exclusive left turn phasing at the Pontiac Trail intersection at Nine and Eleven Mile Roads. After the completion of the FAST-TRAC project the north and southbound left turn movements at each of these locations were given permissive/protected left turn phasing. The posted speed limit on Pontiac Trail was 35 miles per hour immediately outside the core commercial district and 45 miles per hour in the vicinity of Nine and Eleven Mile Roads.

4.2 “After” Data

The collection of the “after” traffic volume and signal timing information took place during the week of May sixth through May tenth, 1996. The “after” data elements of the system included the traffic volume and traffic signal timing. Both of these statistics were collected automatically by the SCATS

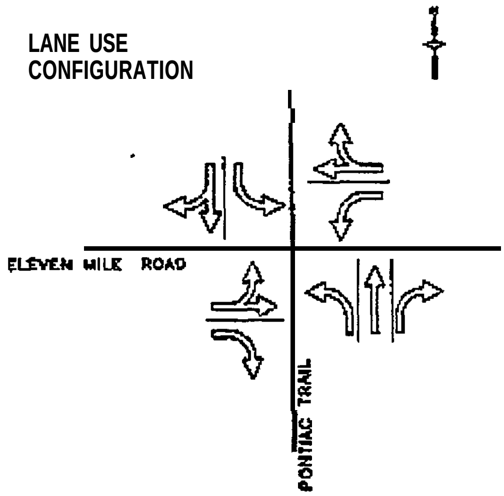
Figure 1: Timing plan for the fixed time signal



SIGNAL TIMING INTERVALS

INTERVALS	MOVEMENT N/S	MOVEMENT E/W	TIME INTERVAL
1	GREEN	RED	48 SEC.
2	AMBER	RED	4 SEC.
3	RED	RED	1 SEC.
4	RED	GREEN	22 SEC.
5	RED	AMBER	4 SEC.
6	RED	RED	1 SEC.

CYCLE LENGTH: 80 SEC.



SIGNAL TIMING INTERVALS

INTERVALS	MOVEMENT N/S	MOVEMENT E/W	TIME INTERVAL
1	GREEN	RED	34 SEC.
2	AMBER	RED	4 SEC.
3	RED	RED	1 SEC.
4	RED	GREEN	26 SEC.
5	RED	AMBER	4 SEC.
6	RED	RED	1 SEC.

CYCLE LENGTH: 70 SEC.

data processing system.

Each of the signals controlled by SCATS incorporates a system of video imaging cameras which are positioned to record the presence of vehicles for critical movements at the stop line. A "critical movement" is a left turn, right turn, or through movement which is allotted green time during the signal cycle. At a minimum, through movements must be recorded to allot green time to the approaches. At locations where a separate left turn phasing is used, detection zones are added to record the left turn traffic volumes. No right turn traffic volume information is collected in South Lyon. The right turn and through traffic both use the through lane and are unopposed by conflicting traffic movements.

The SCATS output file consists of a stream of cycle-by-cycle information containing key performance statistics for each critical movement on the constituent approaches. It also contains signal control information like the current mode of operation, (tactical or strategic), the primary split plan and cycle length, the controlling strategic approach, and the intersection degree of saturation, Since all six of the signalized intersections were converted to SCATS control, all of the necessary traffic volume information was collected remotely, using the SCATS/Autoscope data processing system. Unfortunately, not all of the intersections were equipped to collect all of the data that was required for analysis in this study. The SCATS configuration at the intersections of Pontiac Trail at McHattie Street and Reynold Sweet Parkway did not allow for the collection of left turn movement data. The traffic volumes collected by the SCATS system at these locations are limited solely to the through movements. Using this information signal timings are interpreted by SCATS in the local controller and not at the regional traffic operation center. Under this mode of operation, the cycle by cycle data is not saved. Thus it was not possible to assess the delay at these two intersection. Video tapes of the arrival and departure of vehicles were made for the intersections of Pontiac Trail and Nine Mile Road, and Pontiac Trail and Eleven Mile Road. The Nine Mile Road intersection operates near capacity while the 11 Mile Road intersection has lower volumes. These two intersections were selected to determine the benefits of SCATS at different levels of congestion.

5.0 Results

Two approach movements at the intersections of Nine Mile and Eleven Mile Roads with Pontiac Trail were video taped on Wednesday, December sixth, Thursday, December seventh, and Friday, December eighth 1995. The delay data was recorded from 2:30 to 5:00 p.m. Taping during the remainder of the evening peak period was not possible due to the low visibility conditions after 5:00 p.m.

Two cameras were positioned at the southeast corner of the Nine Mile Road/Pontiac Trail intersection. The cameras were aimed to record oncoming traffic on the north and west approaches to the intersection. Two different cameras were positioned on the southwest comer of the Eleven Mile Road/Pontiac Trail intersection. These cameras were aimed to record oncoming traffic on the north and east approaches to the intersection. Data reduction was conducted using the video tapes and a stop watch. Although time consuming, this method of data collection and reduction resulted in accurate and detailed time measurements of individual vehicles. Tapes could be played, rewound, and replayed to record the arrival and delay characteristics for simultaneously arriving vehicles. To accomplish the same results in a field setting would have required up to eight people per intersection. Summarized results showing the “before” and “after” volume, delay, and signal information is presented in Table 1 through 5 and illustrated in Figure 2 through 9.

At the Pontiac Trail, 11 Mile Road intersection, the total delay was reduced when SCATS was installed. This result was achieved even though there was an increase in the volume of traffic served by the intersection. The total delay increased slightly at the 9 Mile Road intersection, with the increase occurring on the minor approach. The lower volume intersection (Pontiac Trail and Eleven Mile) experienced the largest change in average delay per vehicle. This was probably due to the fact that there was more flexibility in assigning green time and reducing individual phase lengths.

As shown in Table 1, the average delay per vehicle for the major street approach at the 11 Mile Road intersection was reduced by twenty-three percent under SCATS control. Since the volume on the approach was nearly equal in the before and after periods this approach experienced nearly the same reduction in total vehicle-hours of delay. As shown in the last column of Table 1, this was accomplished by allocating additional green time to the N-S movement. Over the two hour observation period, the increase in green time (21%) was almost identical to the decrease in delay.

This reallocation of green time resulted in an increase in delay for the minor flow, as shown in Table 2. The average delay per vehicle increased by fourteen percent, and the total delay increased by thirty-five percent for the westbound traffic approaching the intersection. About half the increase in total delay is accounted for by the eighteen percent increase in volume. Even if the average delay has remained constant, the total delay would have increased by 18 percent because of the volume change.

The reallocation of green time was primarily accomplished by terminating the green phase for E-W traffic rather than by extending the green time for N-S traffic. The average cycle length was shorter under SCATS then it was under fixed time control.

The average delay for these two approaches combined decreased by twelve percent (from 18.9 seconds per vehicle to 16.7 seconds per vehicle) after the SCATS system was installed. The total volume for these two approaches increased by five percent between the before and after periods.

The average delay at the higher volume intersection (9 Mile Road) also decreased after SCATS was implemented, but by a smaller percentage. As shown in Table 3, the reduction in the average delay per vehicle for the major flow was reduced by two percent. Since the volume on this approach also decreased the total delay was reduced by four percent.

The average delay to the minor street approach at this intersection increased by nine percent and total delay increased by fourteen percent (partially due to the increase in volume on this approach). The average delay for those two approaches combined increased by less than two percent after SCATS was installed. This may be accounted for by the green time allotted for left turning traffic.

The N-S traffic was allocated the majority of the green time at this intersection under fixed time control. Under SCATS, the average green time allocation for the through movement at this approach was reduced by ten percent, going from 60 percent of the cycle to 54 percent of the cycle.

The percentage of vehicles required to stop was reduced on three of the four approaches included in the analysis, as shown in Table 5. The major flow (N-S) experienced the largest reduction in the percentage of vehicles required to stop at the intersection. The percentage of vehicles required to stop on the westbound approach on 11 Mile Road decreased from seventy-five percent to sixty-eight percent. However, the total stopped delay increased from 1.63 to 2.01 vehicle hours on this approach. Part of this is due to the increase in volume, and part is due to the reallocation of green time to N-S traffic, thus increasing the delay for those vehicles that arrive at the signal during the red phase.

The percentage of vehicles required to stop on the eastbound approach on 9 Mile Road increased from seventy-four percent to seventy-eight percent. Since the green time allocated to this approach did not change with the implementation of SCATS, this may simply be a result of a different arrival pattern on the days data were collected.

TABLE 1 - Delay for Southbound Traffic at the Pontiac Trail - 11 Mile Road Intersectin (2:30 - 4:30 p.m._

Parameter	Volume	Avg Delay (Sec)	Total Delay (v-hrs)
BEFORE SCATS	842	15.7	3.67
AFTER SCATS	858	12.1	2.88
DIFFERENCE	16	-3.6	-0.79
%	+2%	-23%	-22%

TABLE 2 - Delay for Westbound Traffic at the Pontiac Trail - 11 Mile Road Intersection (2:30 - 4:30 p.m.)

Parameter	Volume	Avg Delay (Sec)	Total Delay (v-hrs)
BEFORE SCATS	235	27.1	1.77
AFTER SCATS	278	30.9	2.39
DIFFERENCE	43	+3.8	0.62
%	+18%	+14%	+35%

TABLE 3 - Delay for Southbound Traffic at the Pontiac Trail - 9 Mile Road Intersection (2:30 - 4:30 p.m.)

Parameter	Volume	Avg Delay (Sec)	Total Delay (v-hrs)
BEFORE SCATS	1285	13.2	4.71
AFTER SCATS	1268	12.9	4.54
DIFFERENCE	-17	-0.3	-0.17
%	-1%	-2%	-4%

TABLE 4 - Delay for Eastbound Traffic at the Pontiac Trail - 9 Mile Road Intersectin (2:30 - 4:30 p.m.)

Parameter	Volume	Avg Delay (Sec)	Total Delay (v-hrs)
BEFORE SCATS	284	29.1	2.29
AFTER SCATS	297	31.6	2.61
DIFFERENCE	13	2.5	0.32
%	+5%	+9%	+14%

TABLE 5 - Percent of Vehicles Stopped and Stopped Delay at the Two Intersections

APPROACH	% Stopped Vehicles Before SCATS	Total Stopped Delay (veh-hrs)	% Stopped Vehicles After SCATS	Total Stopped Delay (veh-hrs)
SB Pontiac Trail at 11 Mile	59%	3.38	42%	2.08
SB Pontiac Trail at 9 Mile	54%	5.74	42%	3.61
WB 11 Mile at Pontiac Trial	75%	1.63	68%	2.01
EB 9 Mile at Pontiac Trial	74%	1.89	78%	2.38
Total		12.64		10.08

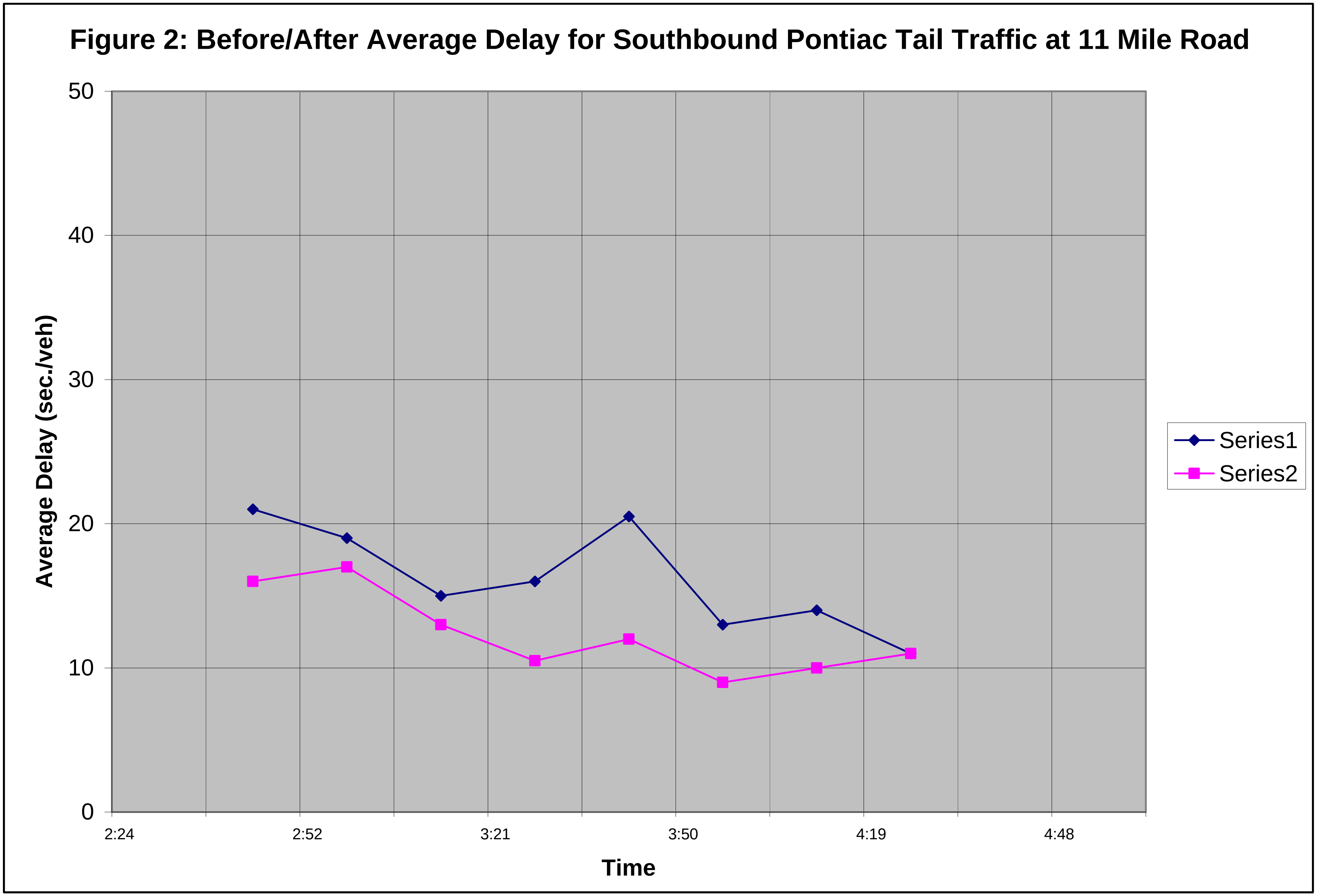


Figure 2: Before/After Average Delay for Southbound Pontiac Tail Traffic at 11 Mile Road
Average Delay (sec./veh)
50
40
30
20
10
0
2:24
2:52
3:21
3:50
4:19
4:48
Time
Series1
Series2

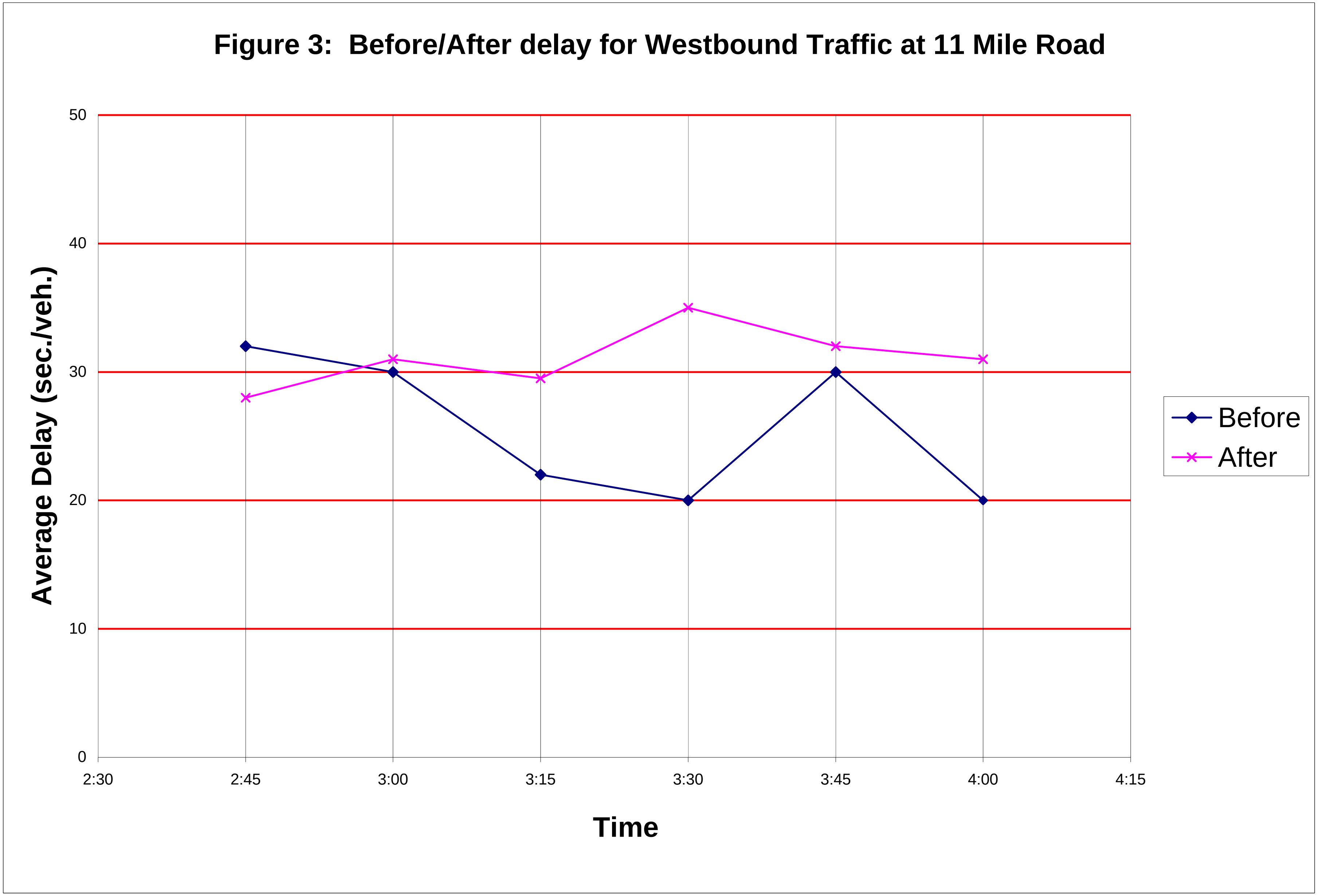


Figure 3: Before/After delay for Westbound Traffic at 11 Mile Road
Average Delay (sec./veh.)
50
40
30
20
10
0
2:30
2:45
3:00
3:15
3:30
3:45
4:00
4:15
Time
Before
After

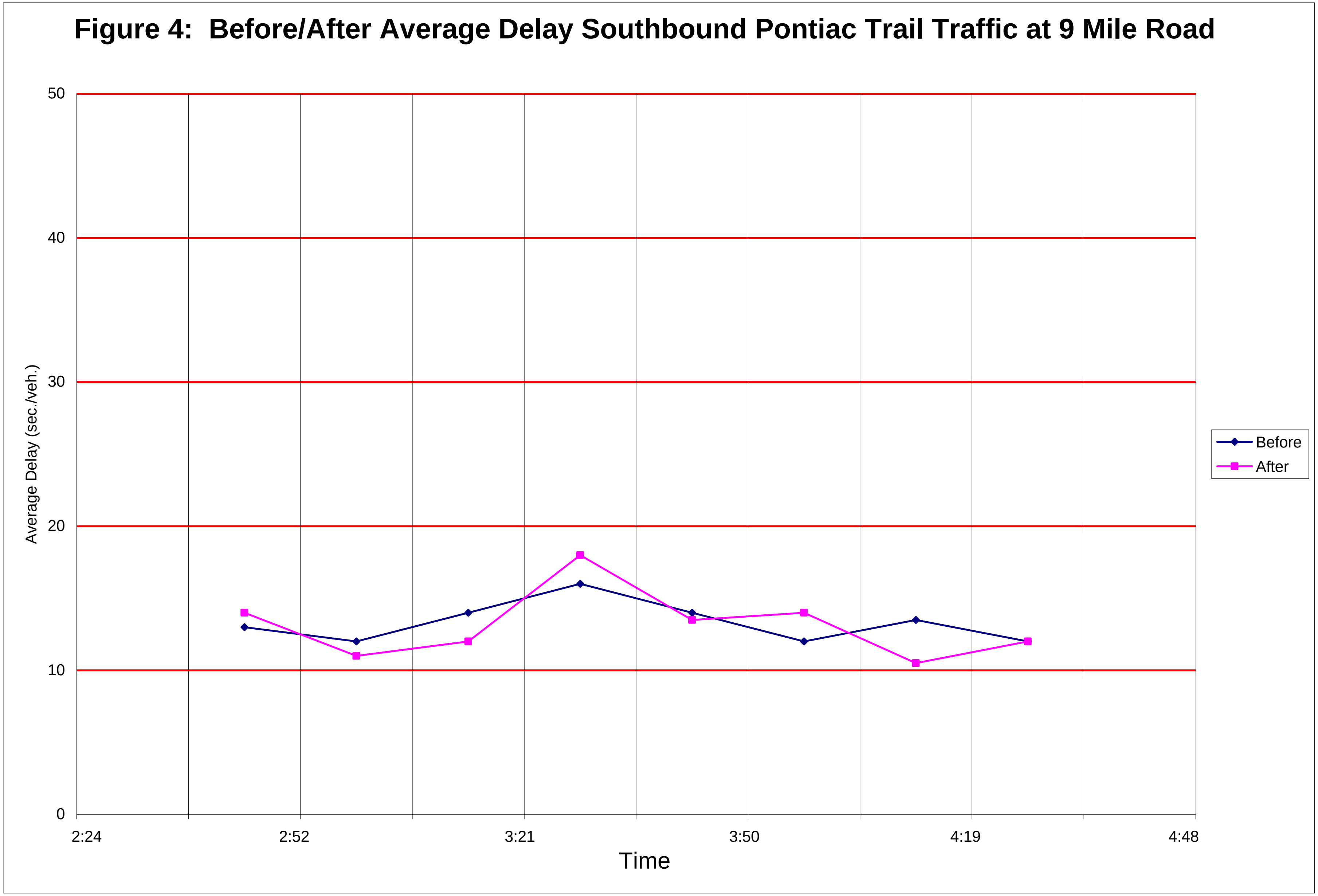


Figure 4: Before/After Average Delay Southbound Pontiac Trail Traffic at 9 Mile Road
50
40
30
20
10
0
Average Delay (sec./veh.)
2:24
2:52
3:21
3:50
4:19
4:48
Time
Before
After

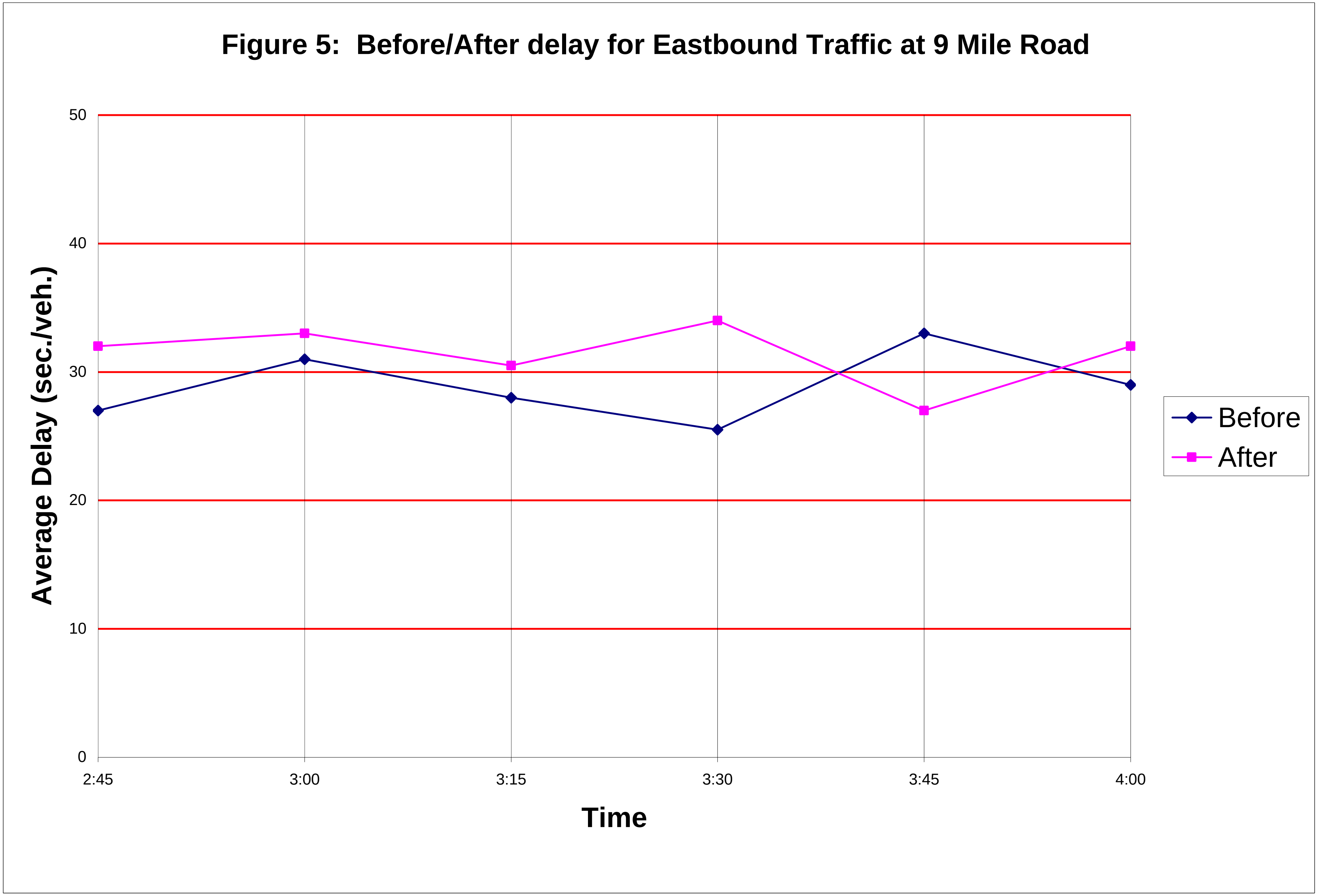
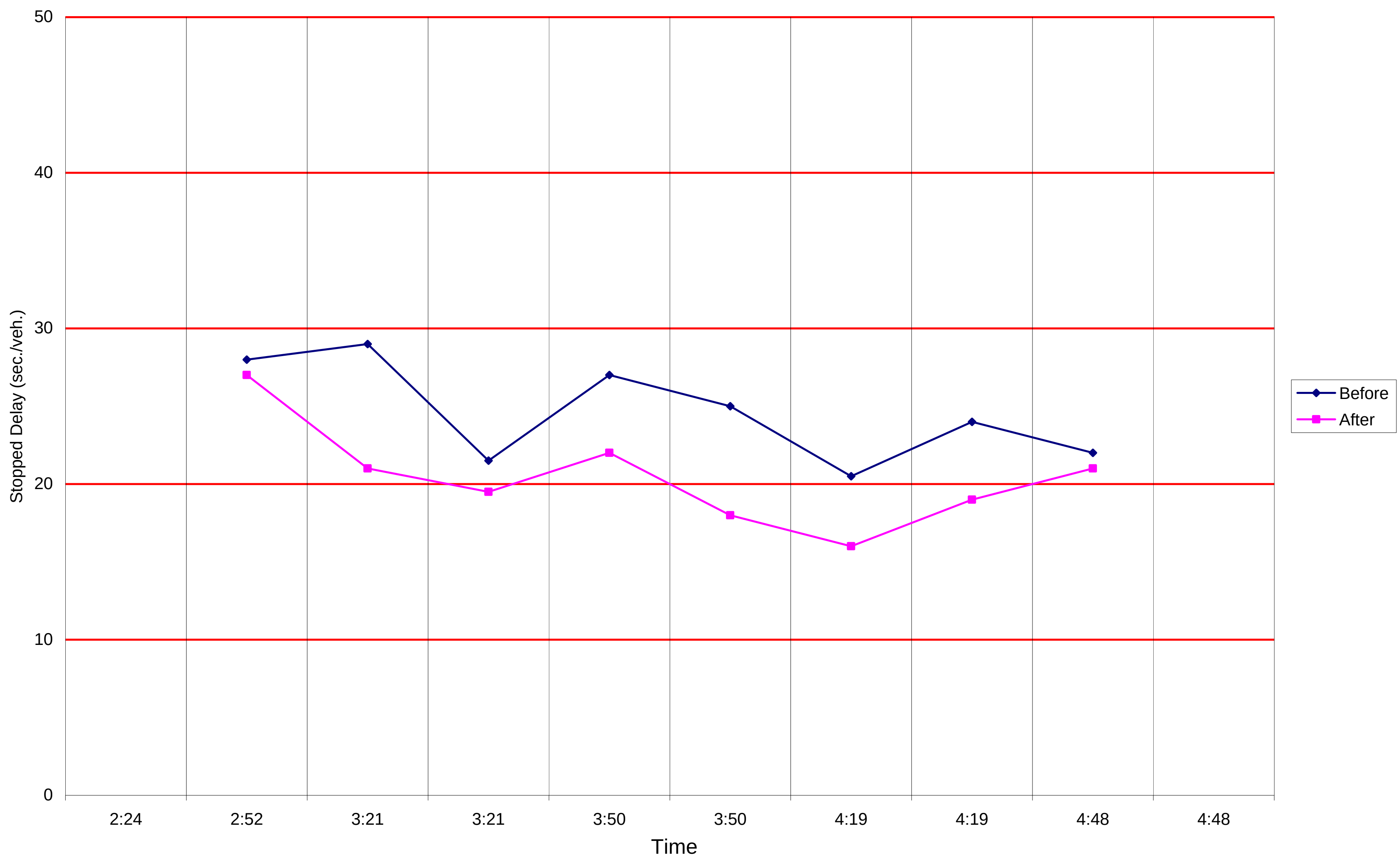


Figure 5: Before/After delay for Eastbound Traffic at 9 Mile Road
Average Delay (sec./veh.)
50
40
30
20
10
0
2:45
3:00
3:15
3:30
3:45
4:00
Time
Before
After

Figure 6: Before/After Stopped Delay For Southbound Pontiac Trail Traffic at 11 Mile Road



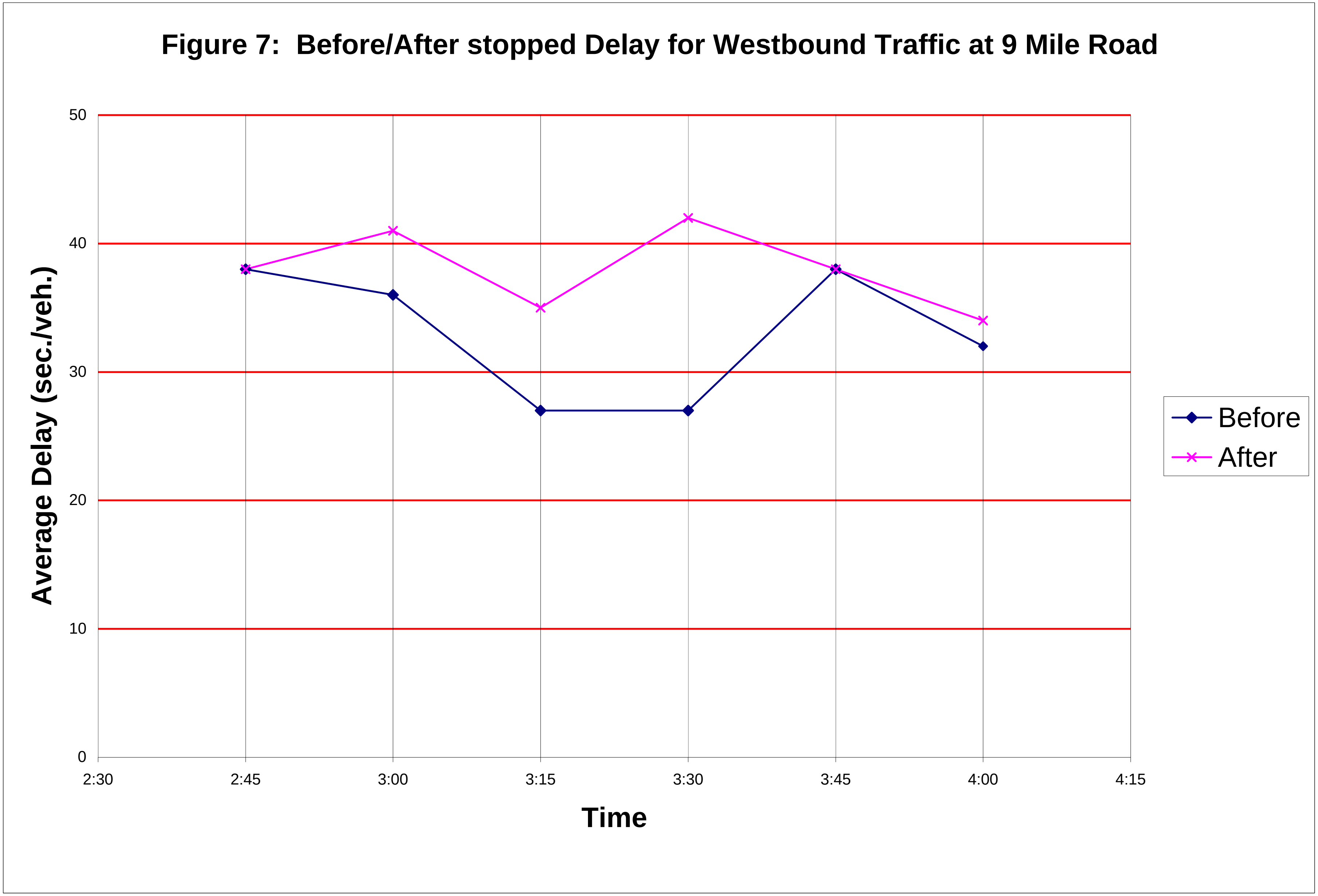


Figure 7: Before/After stopped Delay for Westbound Traffic at 9 Mile Road
Average Delay (sec./veh.)
50
40
30
20
10
0
2:30
2:45
3:00
3:15
3:30
3:45
4:00
4:15
Time
Before
After

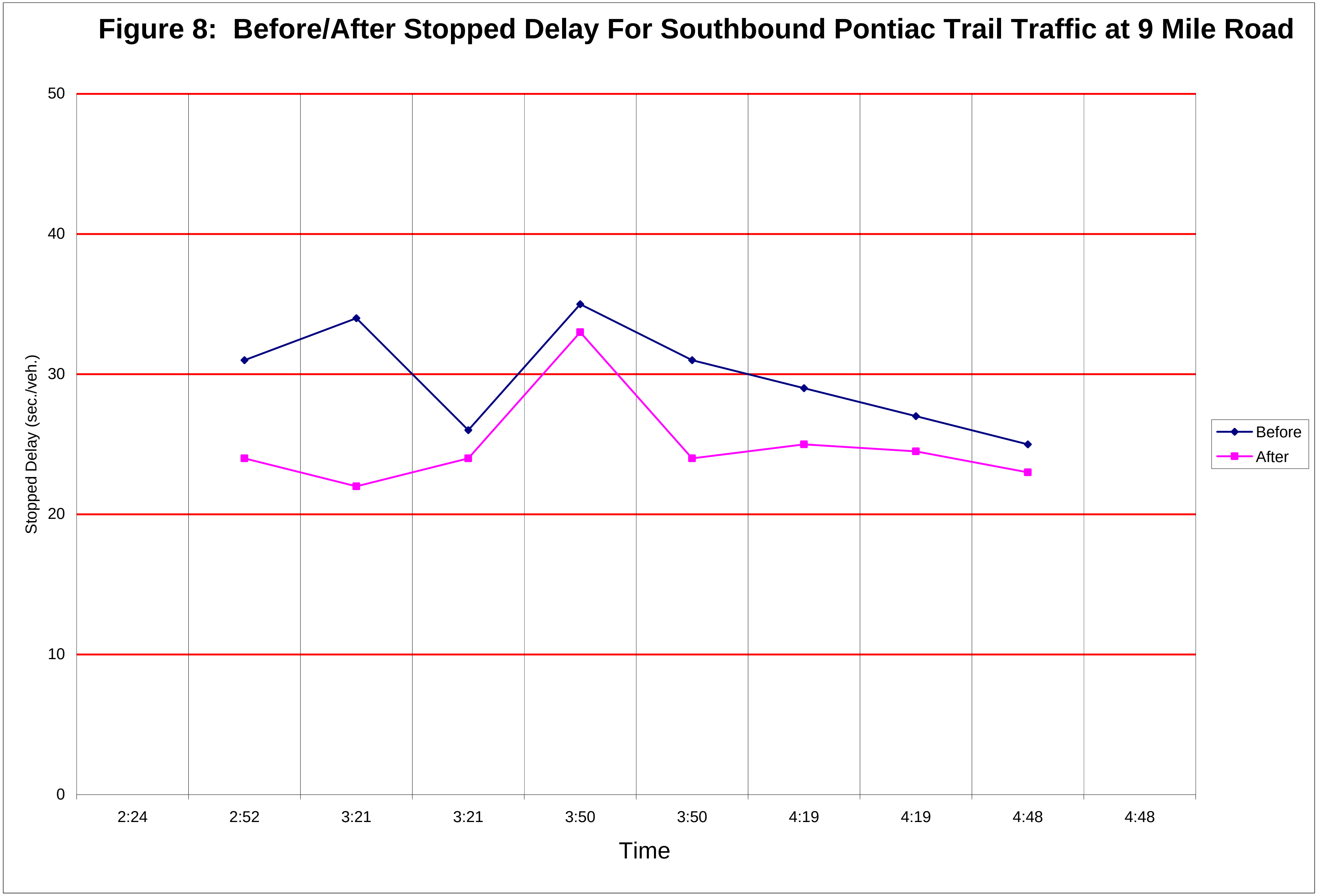


Figure 8: Before/After Stopped Delay For Southbound Pontiac Trail Traffic at 9 Mile Road
Stopped Delay (sec./veh.)
50
40
30
20
10
0
2:24
2:52
3:21
3:21
3:50
3:50
4:19
4:19
4:48
4:48
Time
Before
After

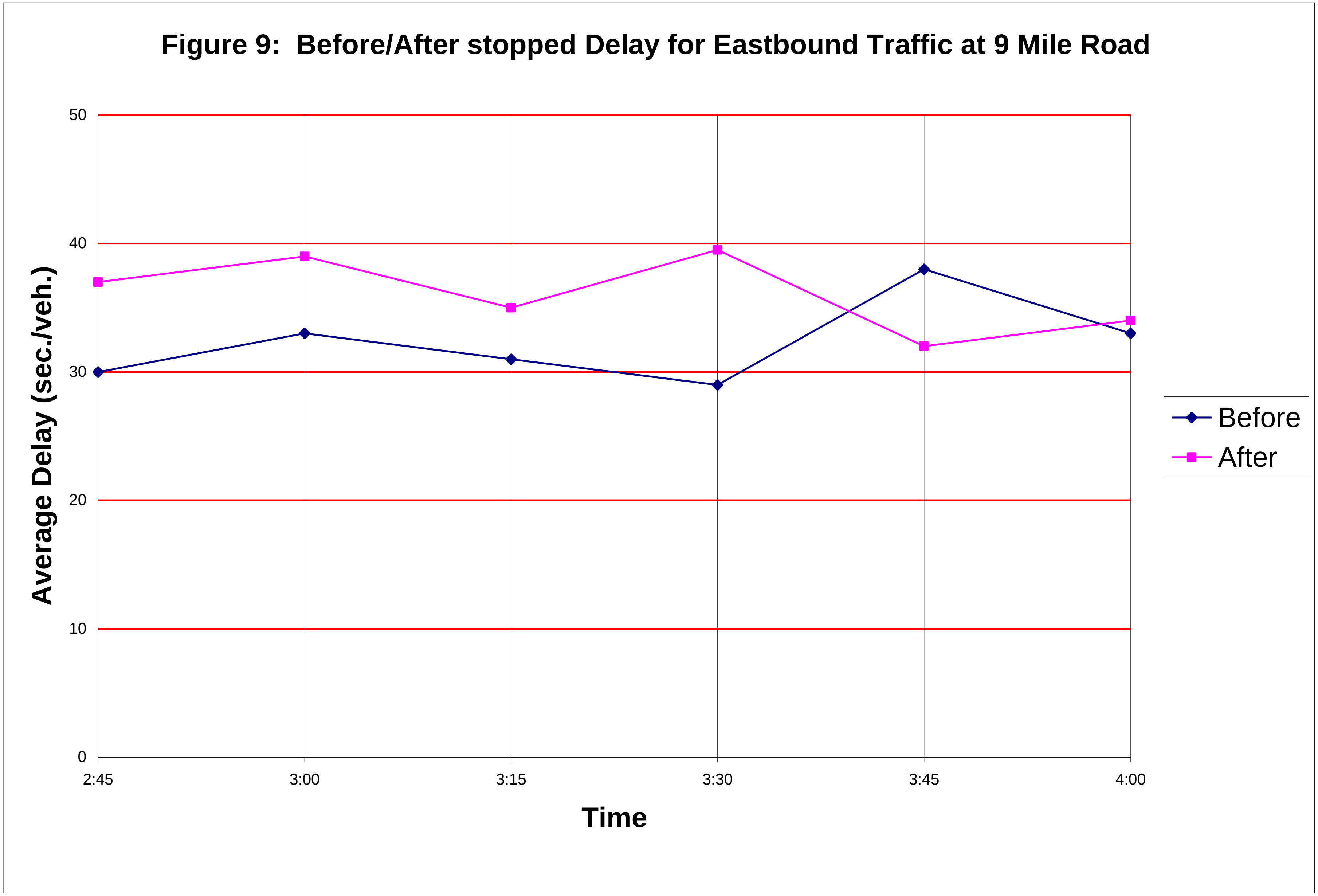


Figure 9: Before/After stopped Delay for Eastbound Traffic at 9 Mile Road
Average Delay (sec./veh.)
50
40
30
20
10
0
2:45
3:00
3:15
3:30
3:45
4:00
Time
Before
After

6.0 Conclusions

The most obvious and direct conclusion which can be drawn from this study is that the use of SCATS resulted in an improvement to the average approach delay in South Lyon when compared to the existing system.

The second conclusion was that SCATS more equally distributes total approach delay to the various approach movements. This is consistent with the SCATS control objective in which the approach degrees of saturation are equalized.

The comparison of delay in South Lyon has been addressed in this study. However, the question of whether or not similar outcomes could be expected in other networks is difficult to answer. The traffic volumes within the South Lyon road system are relatively low compared to those found in the more congested suburbs in Oakland County. When traffic volumes approach or operate above capacity, real time adjustment to signal timings has less impact on the operation of the network. The delay experienced in these situations is not the result of poor signal timings, rather, it results from a lack of capacity provided by the approach geometry or the network road segments.

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200 Engineering Programs Bldg.
2609 Draper Drive
Ann Arbor, MI
48109-2140

Program Offices Telephone:
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